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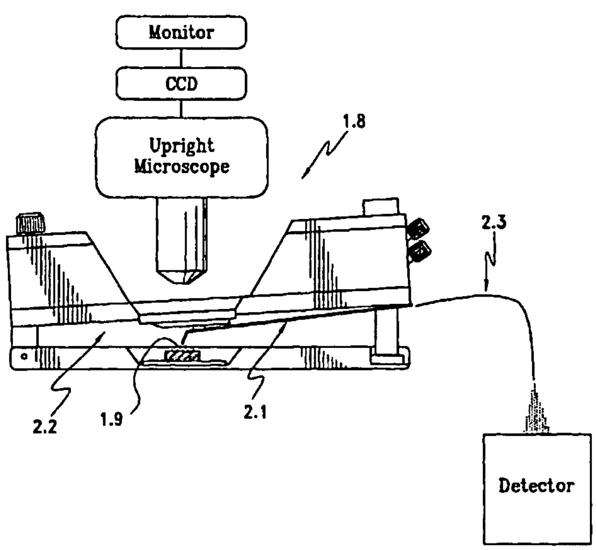
(54) Title: OPTICALLY AMPLIFYING NEAR-FIELD OPTICAL SIGNALS



(57) Abstract: The present invention resolves a fundamental problem in near- field optics by overcoming the limitation inherent in the low signal that is associated with near-field optics through amplification of the signal that has passed through a near-field optical aperture or has been generated by a near-field optical aperture using an optical amplifier in a standard mode of operation or by noiseless optical amplification using phase sensitive fiber amplifiers or other types of amplification that reduce noise.

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Optically Amplifying Near-field Optical Signals

1. Field of Invention

Overcoming the fundamental problem of signal limitations in near-field optics that limits the resolution and other parameters that are achievable in near-field scanning optical microscopy (NSOM)

2. Background of invention

Near-field optics uses a subwavelength aperture usually at the end of a tapered glass structure to either illuminate or collect light from an object [A. Lewis, M. Isaacson, E. Betzig and A. Harootunian, "Near-Field Scanning Optical Microscopy", United States Patent Number 4,917,462]. This allows resolution to be obtained that is well beyond that diffraction limit. A major problem with this technique is the amount of light that can illuminate a sample with such an aperture in illumination mode or the amount of light collected by such an aperture in collection mode is severely limited. This limited signal limits the resolution, speed and the multiplexing that is possible with this signal. This has been a fundamental problem in near-field optics.

3. State of Prior Art

An approach has not been devised to overcome the fundamental problem in near-field optics, as outlined in the Background of the Invention.

4. Summary of Invention

The present invention resolves a fundamental problem in near-field optics by overcoming the limitation inherent in the low signal that is associated with near-field optics. It amplifies the signal that has passed through a near-field optical aperture or has been generated by a near-field optical aperture using an optical amplifier in a standard mode of operation or by noiseless optical amplification using phase sensitive fiber amplifiers or other types of amplification that reduce noise.

5. Brief Description of Drawings

The foregoing, and additional objects, features and advantages of the present invention will be understood by those of skill in the art from the following detailed description of a preferred embodiment, taken with the accompanying drawings, in which:

Fig. 1 is a diagrammatic illustration of the illumination of a sample by light from a subwavelength aperture at, for example, the end of a tapered glass structure;

Fig. 2 is a diagrammatic illustration of the collection of light from a sample by a subwavelength aperture; and

Fig. 3 is a diagrammatic illustration of an improved light collection device, wherein collected light is supplied through an optical amplifier specific for the wavelength of the collection radiation.

6. Detailed Description of Invention

Fig. 1 illustrates the illumination of an object (illumination mode), where light 1.0 of a given wavelength is passed through a subwavelength aperture 1.1. The two objects 1.2 and 1.3 are separated by less than half the wavelength of the incident light 1.0, and cannot be resolved in the far field of the aperture, but they can be resolved when at locations 1.2′ and 1.3′ in the near field using an aperture that is smaller than the wavelength of the light. .

Fig. 2 illustrates a collection mode, where light 1.4 is collected by a subwavelength aperture 1.5, which may be at the end of a tapered glass structure. In this case, two emitting objects 1.6 and 1.7 in the near field of the aperture can be resolved, but the amount of light that can be collected is severely limited.

In accordance with the invention the problem presented by the low amount of light associated with near-field optics is overcome by amplifying the signal that has passed through a near-field optical aperture or has been generated by a near-field optical aperture,

using an optical amplifier, phase sensitive fiber amplifiers, or the like.

The simplest emulation to describe this invention is in standard collection mode near-field optics as described above and illustrated at 1.8 in Figure 3. In this mode of operation light is collected from an emitting source 1.9 through a sub-wavelength aperture usually, but not always, at the end of a tapered metal coated optical fiber 2.1 held in a near-field optical microscope 2.2. The light collected by this aperture is then transmitted through an amplifier of electromagnetic radiation 2.3 that is specific for the wavelength of the collected radiation. Presently, such amplifiers exist at specific wavelengths with those that have the optimum characteristics existing at wavelengths that are within those presently used for telecommunication transmissions.

To improve the signal to noise in the above approach to signal enhancement in near-field optics this approach can be used with schemes that have been devised to allow for noiseless amplification of not a near-field optical source, but images. These schemes [D. Levandovsky, M. Vasilyev and P. Kumar, Indian Academy of Sciences 56, 281 (2001) and S-K Choi, M. Vasilyev and P. Kumar, Phys. Rev. Lett. 83, 1938 (1999)] are based on phase sensitive amplification. Thus, the invention not only uses an optical amplifier for amplification but also can increase the signal to noise ratio. This resolves a fundamental problem in near-field optics, and has vast

potential in all areas to which near-field optics can be applied. Furthermore, in the collection mode geometry the light that is amplified after the aperture at the tip of fiber 2.1 has collected the light cannot damage the tip, as is the case when light is transmitted through a subwavelength tip. Since in one emulation of this scheme amplification occurs after tip collection, another major problem, tip damage, is averted.

The method designed here can be applied to other emulations of near-field optics besides the collection mode where, for example, the amplifier is placed after transmission or collection from the sample when a sample is illuminated by a subwavelength tip.

7. Advantages Over Prior Art

No other approach has allowed the resolution of this fundamental problem in near-field optics.

8. Applications

The resolution of this fundamental problem in near-field optics has numerous applications. In one area, there can be amplification of small signals in a telecom network that are sensed by near-field optical sensors. In another, small apertures can be used in data storage applications without giving up on the signal that is needed

for rapid reading. In practically every area where light has reached the fundamental limit of diffractive optics this invention can be applied together with near-field optics.

What is claimed is:

1. A device in which a signal that has passed through an near-field optical aperture is amplified by an optical amplifier to resolve the signal problems in near-field optics.
2. A device as in claim 1 in which there is noiseless optical amplification.
3. A method in which a signal that has passed through a near-field optical aperture is amplified by an optical amplifier to resolve the signal problems in near-field optics.
4. A method as in claim 3 in which there is noiseless optical amplification .

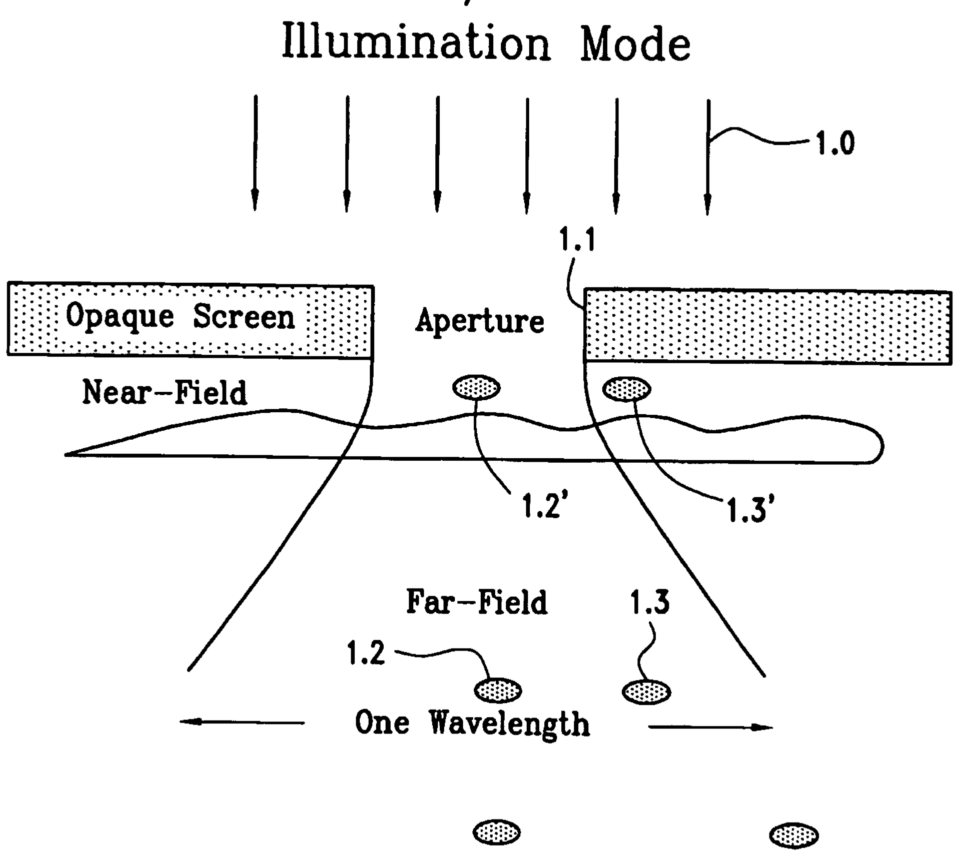
Illumination Mode
1.0
1.1
Opaque Screen
Aperture
Near-Field
1.2'
1.3'
Far-Field
1.3
1.2
One Wavelength

FIG. 1

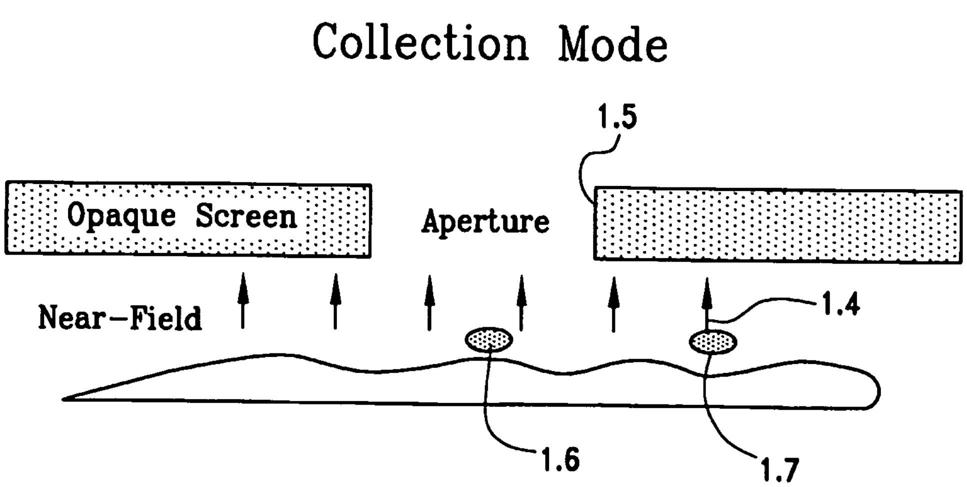
Collection Mode
1.5
Opaque Screen
Aperture
Near-Field
1.4
1.6
1.7

FIG. 2

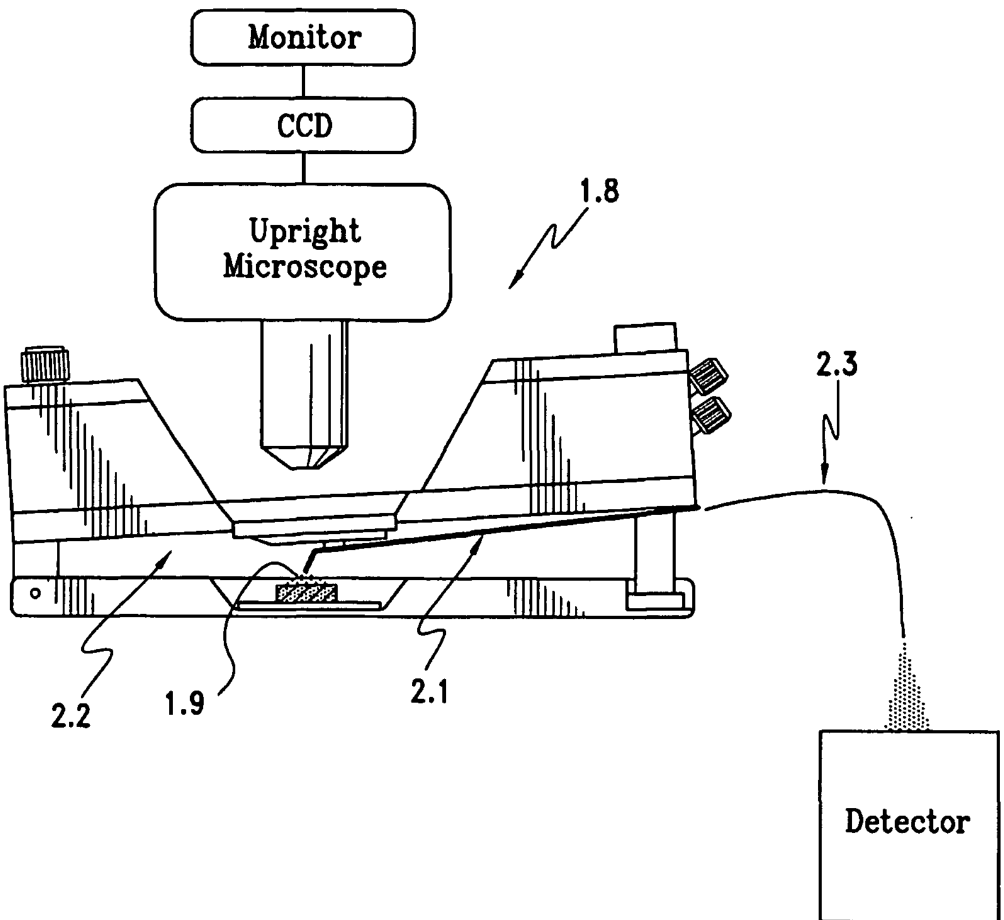

FIG. 3